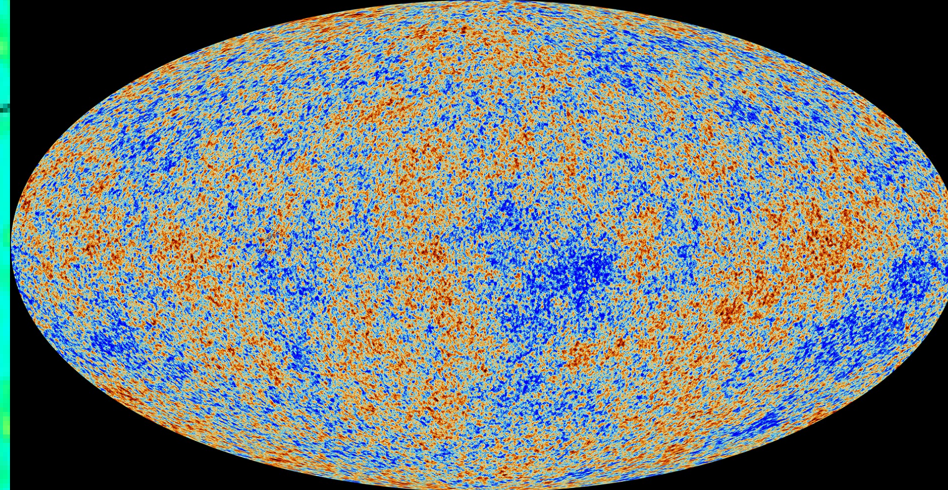
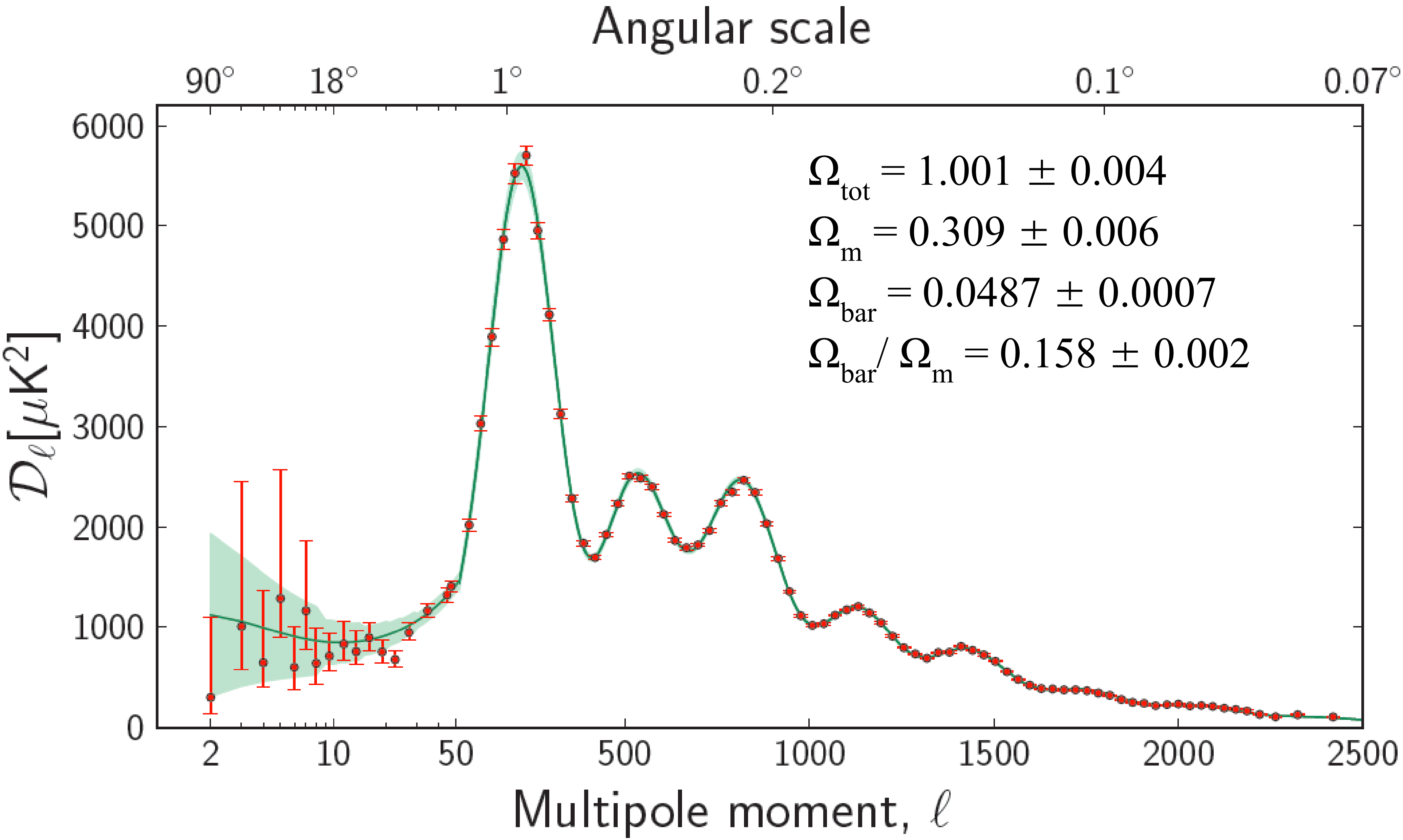


Cornell
April 2016

The baryon content of dark halos

Simon White
Max Planck Institute for Astrophysics

The cosmic baryon fraction



$\Omega_{tot} = 1.001 \pm 0.004$

$\Omega_m = 0.309 \pm 0.006$

$\Omega_{bar} = 0.0487 \pm 0.0007$

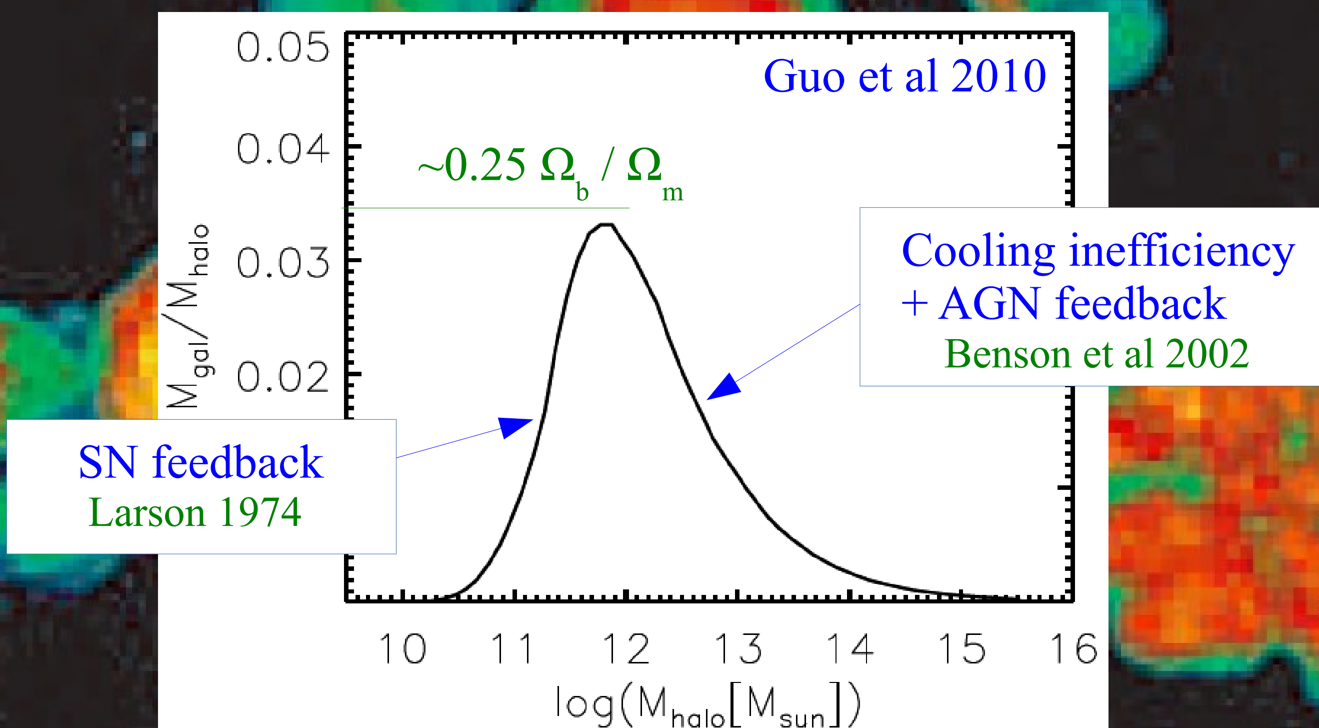
$\Omega_{bar} / \Omega_m = 0.158 \pm 0.002$

Planck 2015

<25% of the expected baryons in dark halos lie in the central galaxy

In rich clusters most of the expected baryons are in the IGM, but in lower mass halos most are “missing”

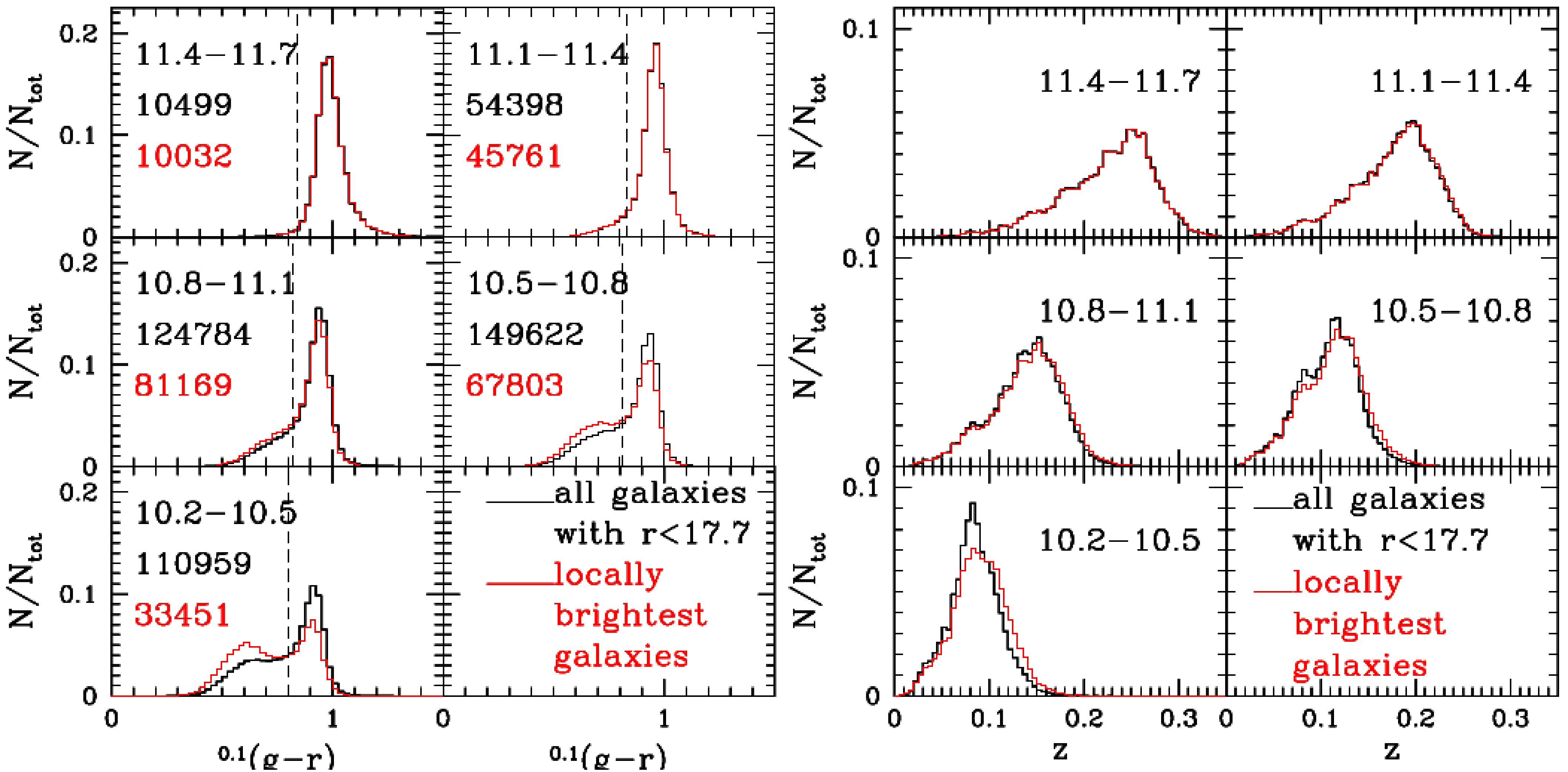
Blown out? How far? What state are they in? How to see them?



Locally brightest galaxies as halo proxies

SDSS/DR7: r < 17.7, z > 0.03
Brighter than all neighbours with $r_p < 1.0$ Mpc, $\Delta z < 1{,}000$ km/s

Planck Collaboration 2013



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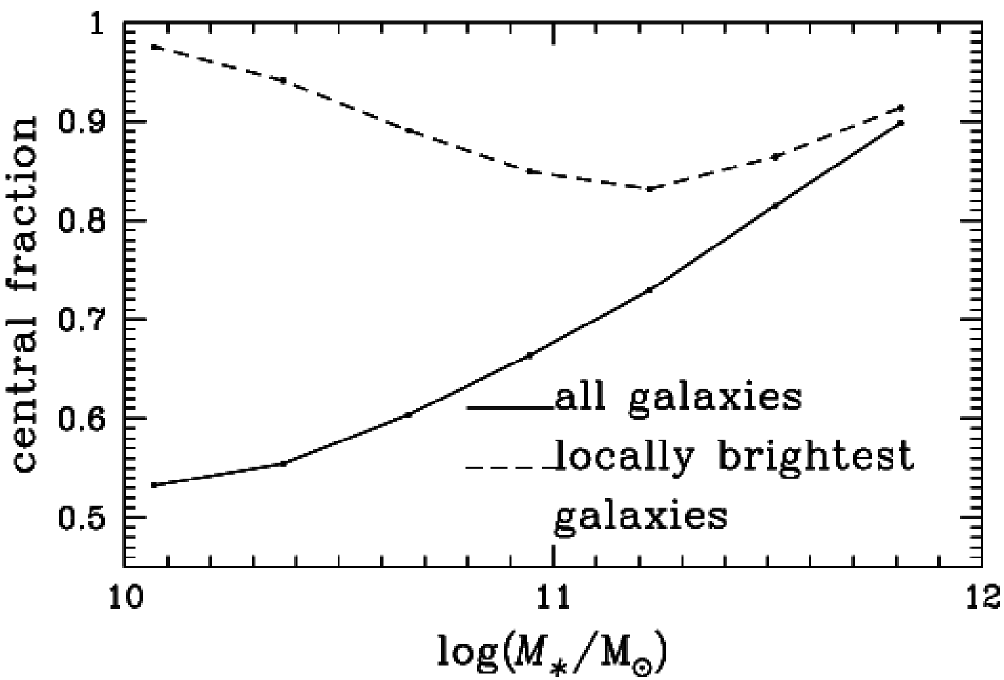
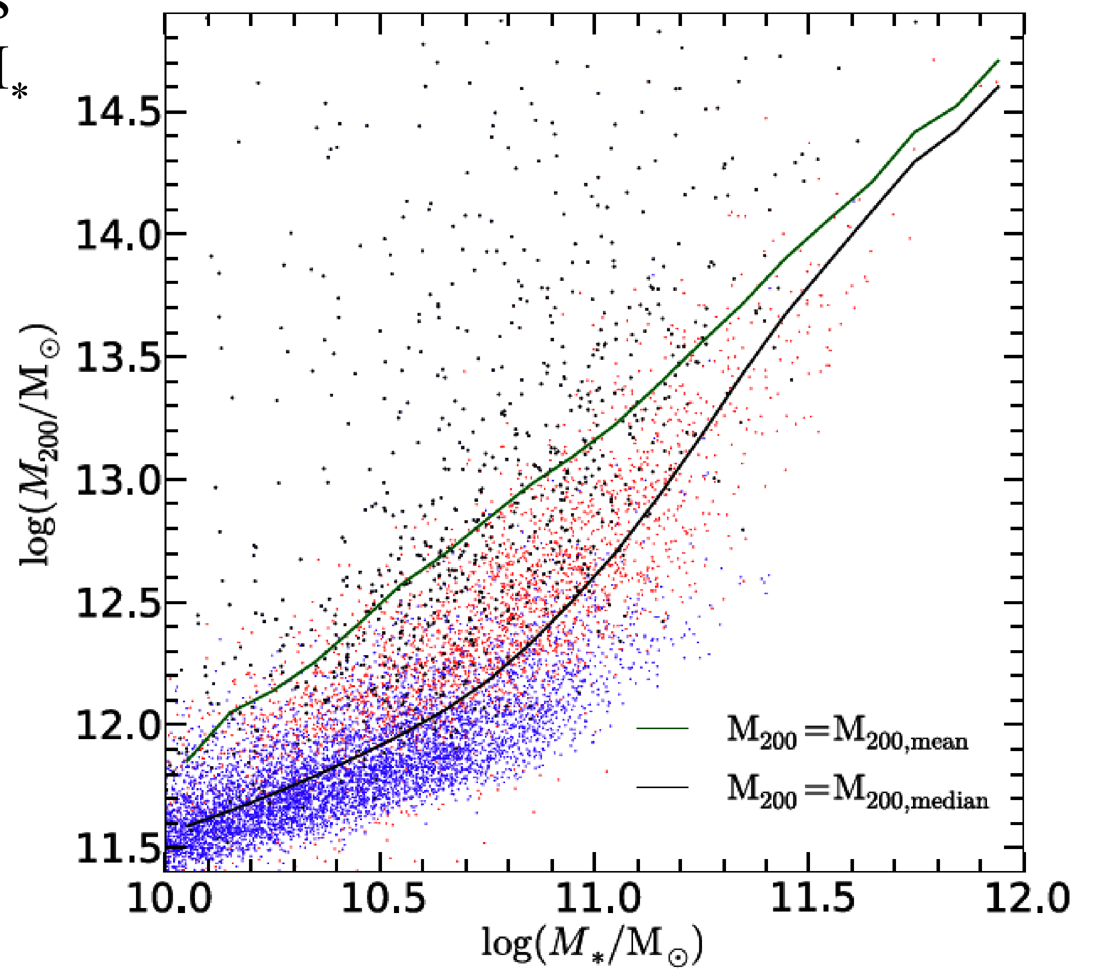
Mock light-cone: Guo et al (2013) simulation in the WMAP7 cosmology

>83% of LBGs are halo centrals

Large spread in M_{200} at given M_*

Planck Collaboration 2013





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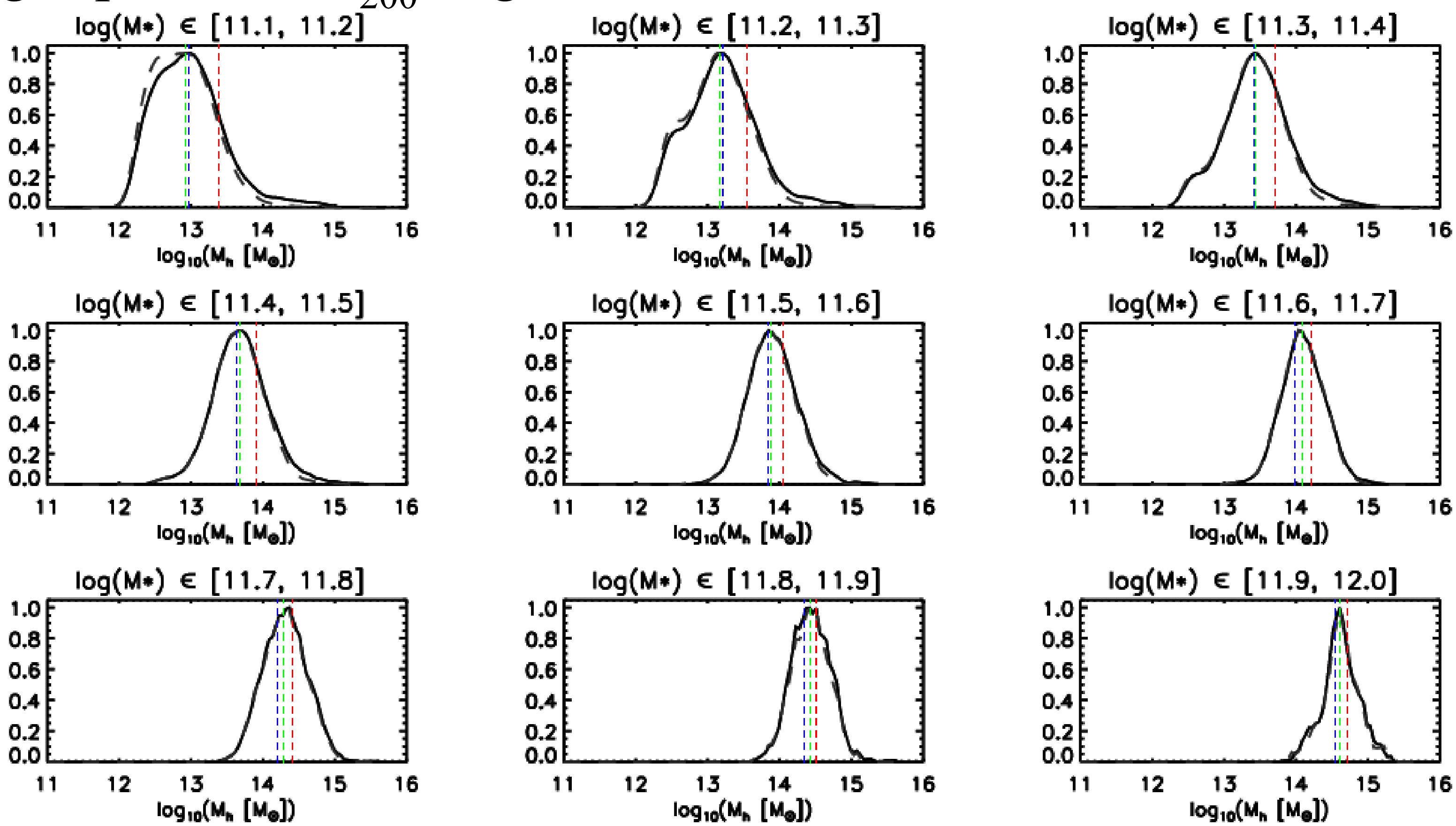
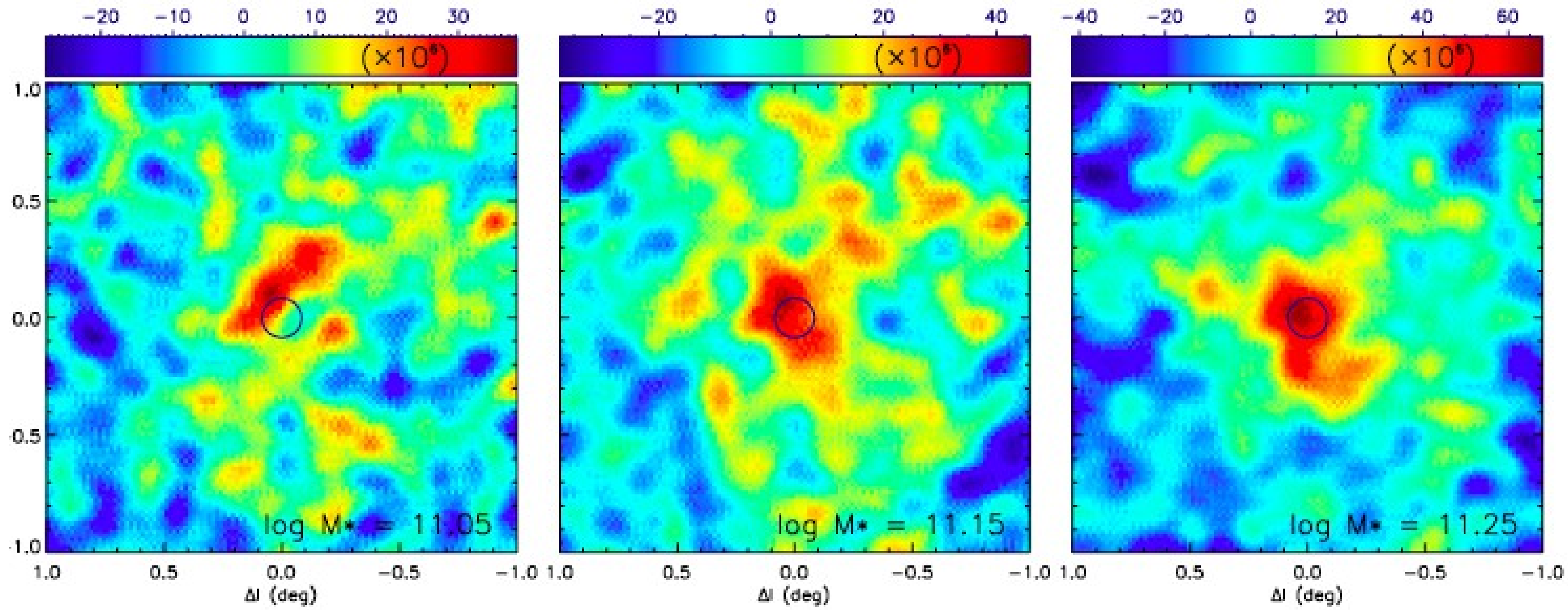
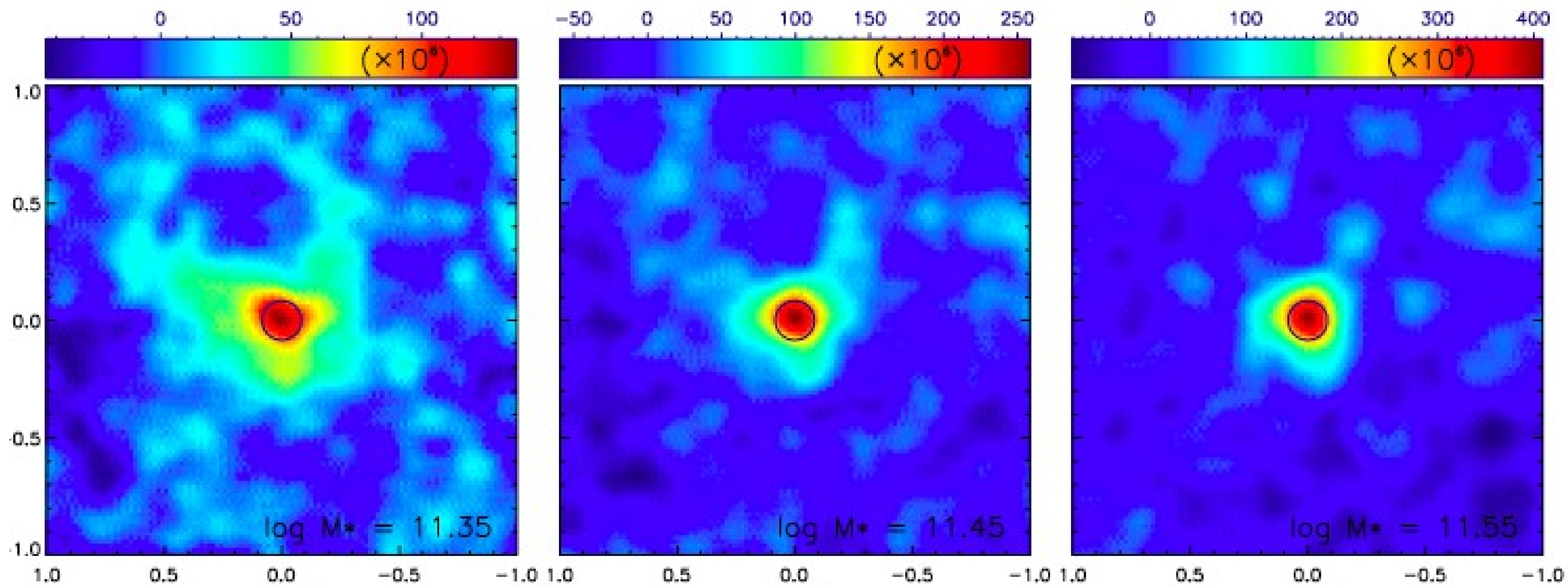


Stacked images of the Planck SZ signal from LBGs

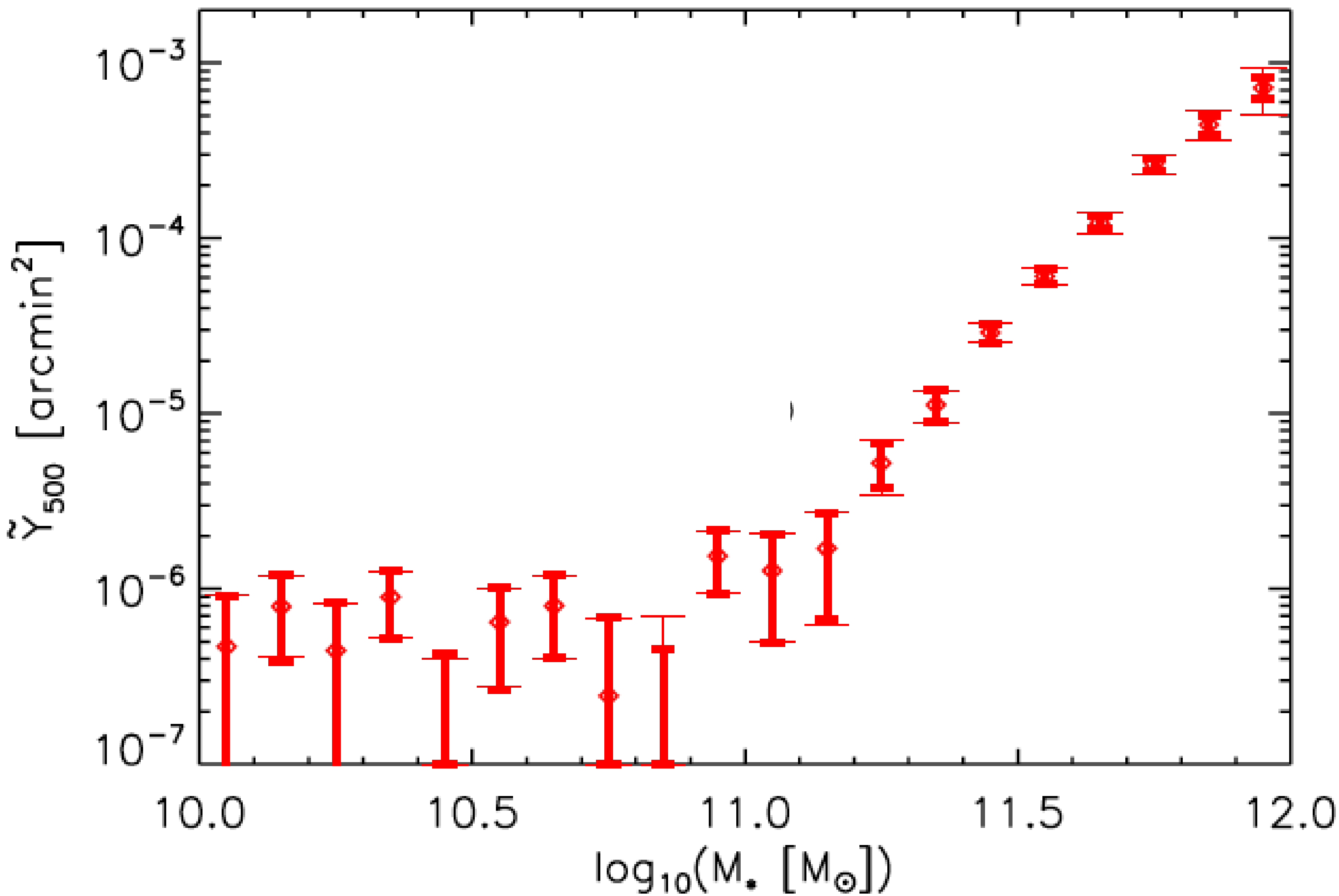


Planck Collaboration 2013



Stacked Planck SZ signal from LBGs

Planck Collaboration 2013



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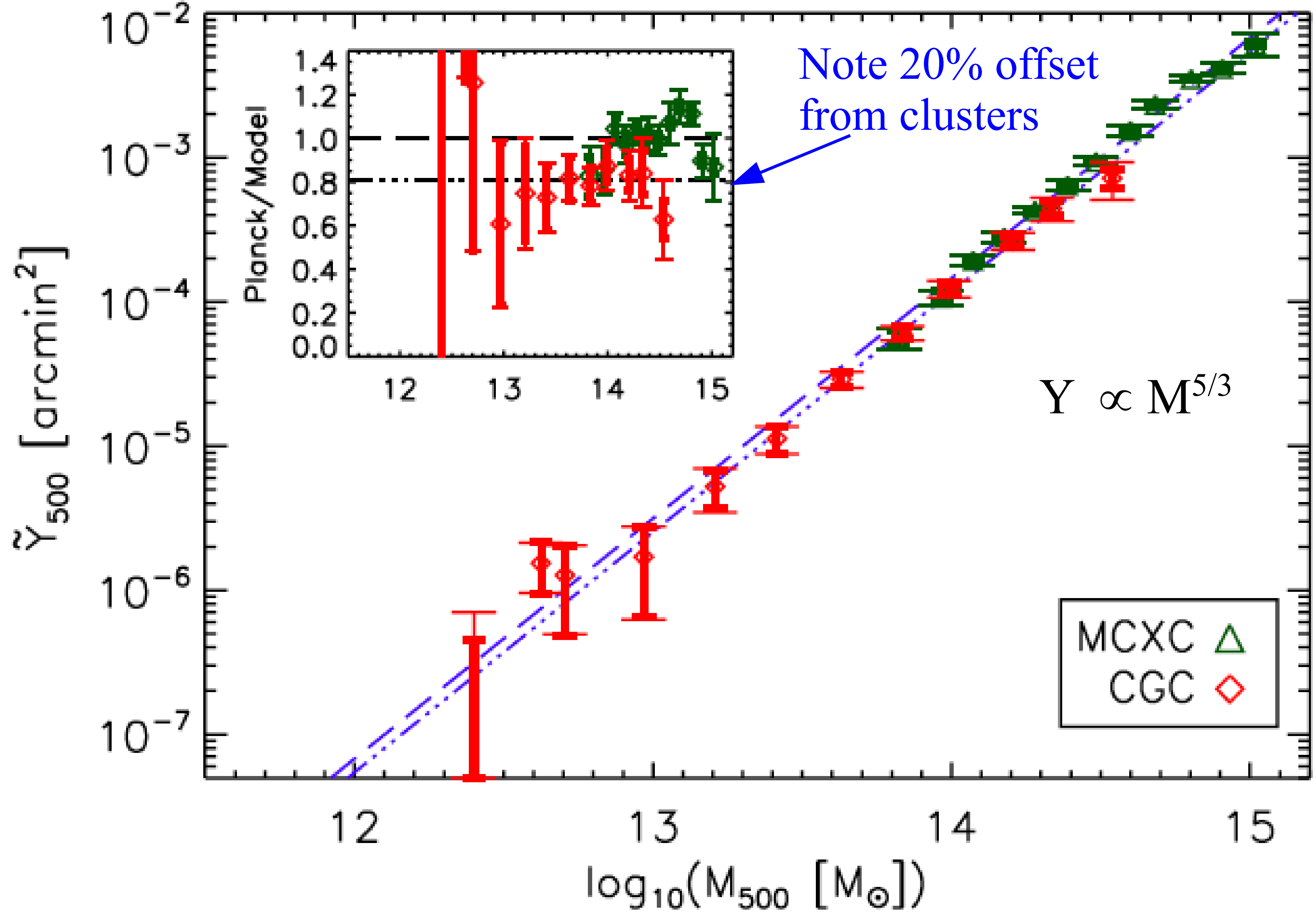
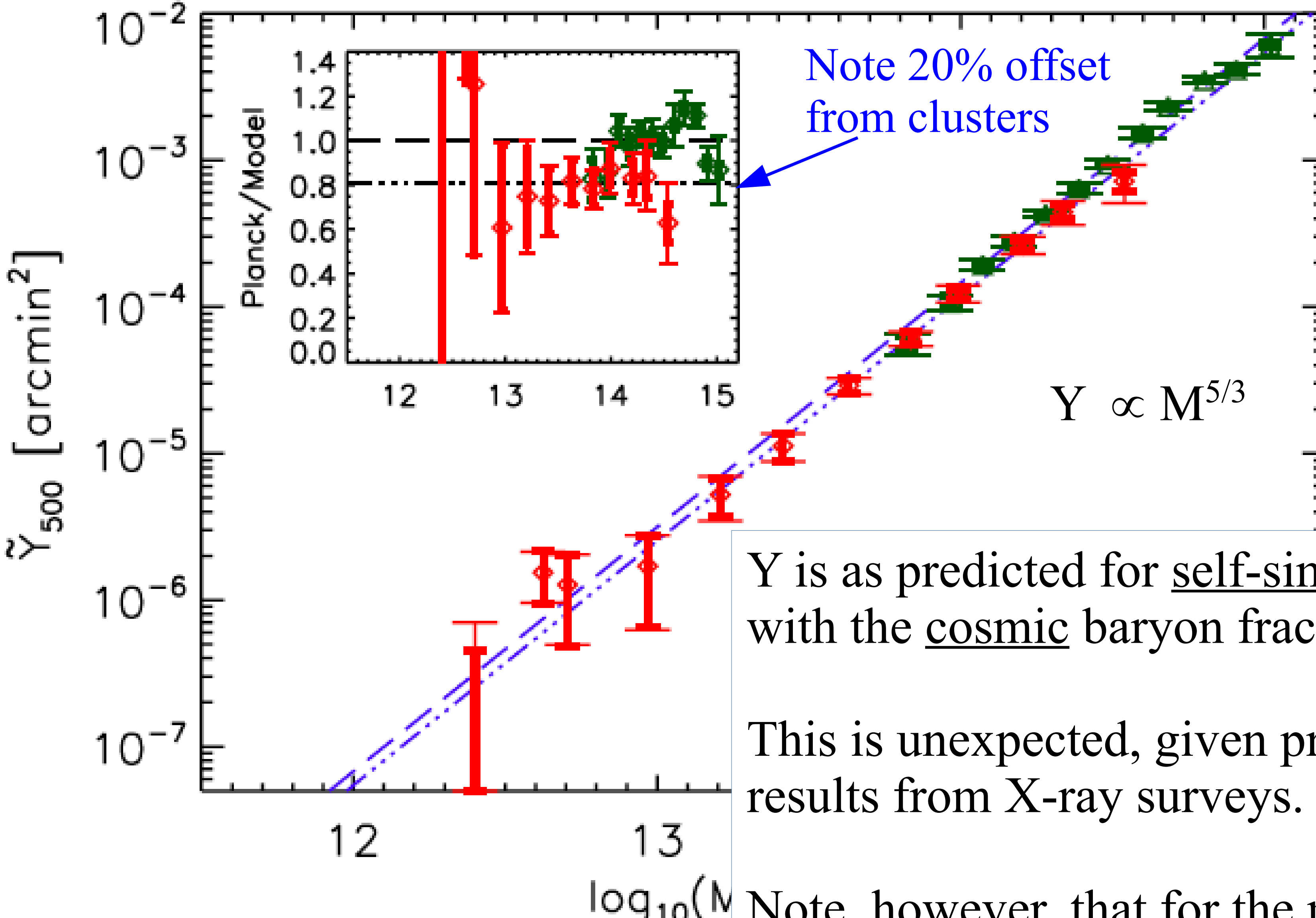


Effective mean halo mass $M_{500}(M_*)$ for each bin is derived from the simulation

Stacked Planck SZ signal from LBGs

Planck Collaboration 2013



Y is as predicted for self-similar halos with the cosmic baryon fraction

This is unexpected, given previous results from X-ray surveys.

Note, however, that for the majority of LBGs Planck does not resolve R_{500}

Stacked Rosat X-ray signal from LBGs

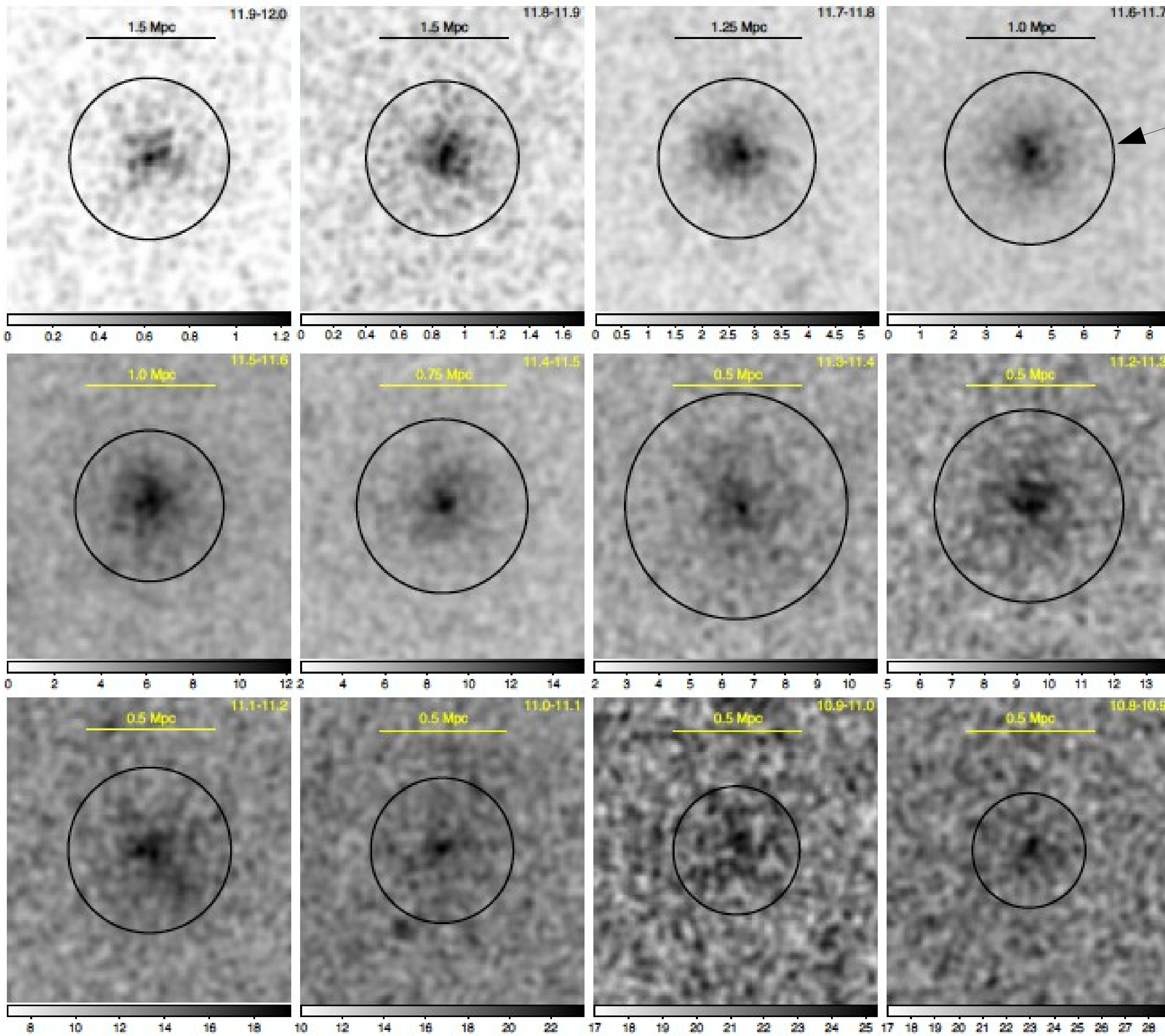
log M_*

Anderson et al 2015

11.9 – 12.0

11.5 – 11.6

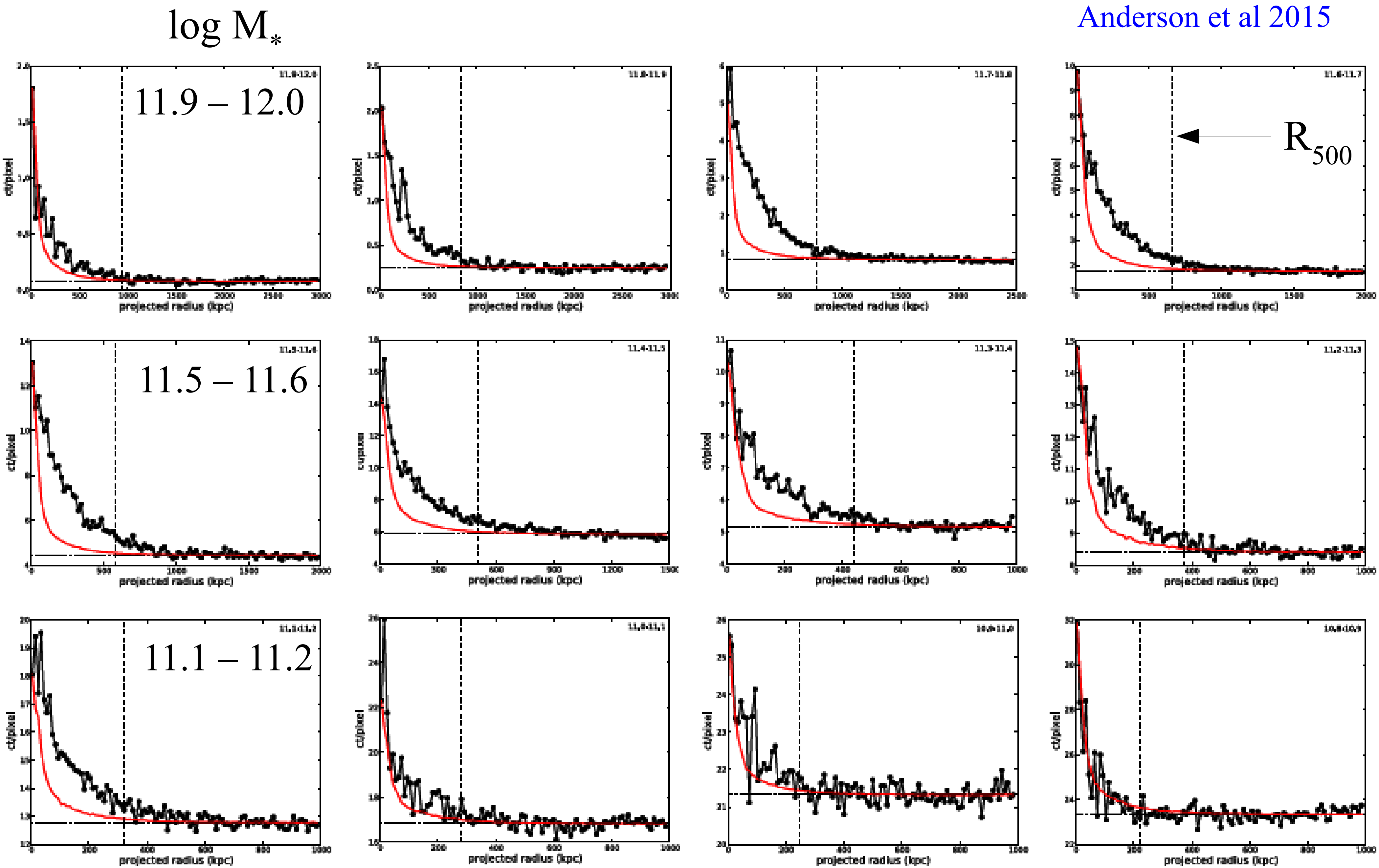
11.1 – 11.2



R_{500}

Stacked Rosat X-ray signal from LBGs

Anderson et al 2015



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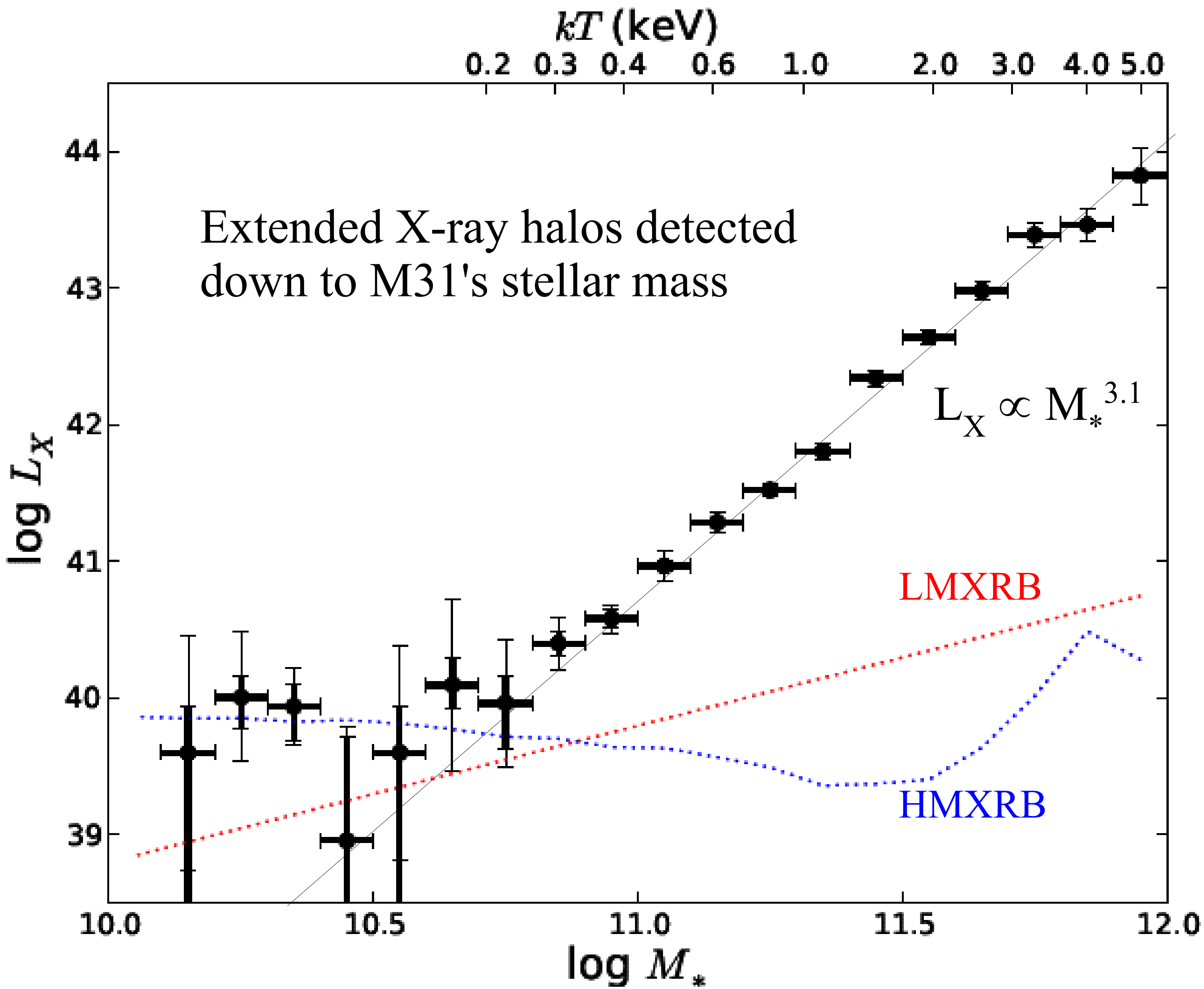

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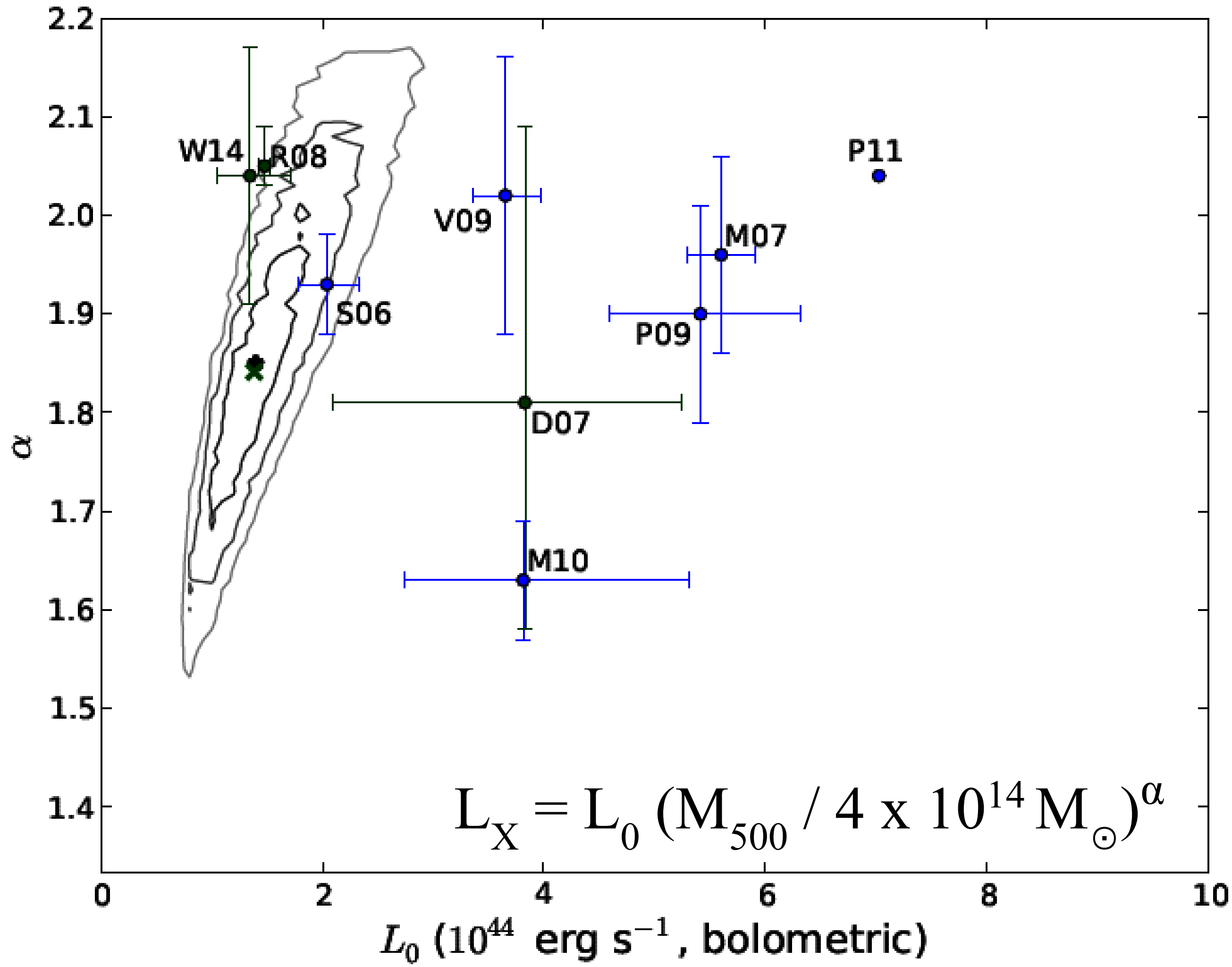


Anderson et al 2015

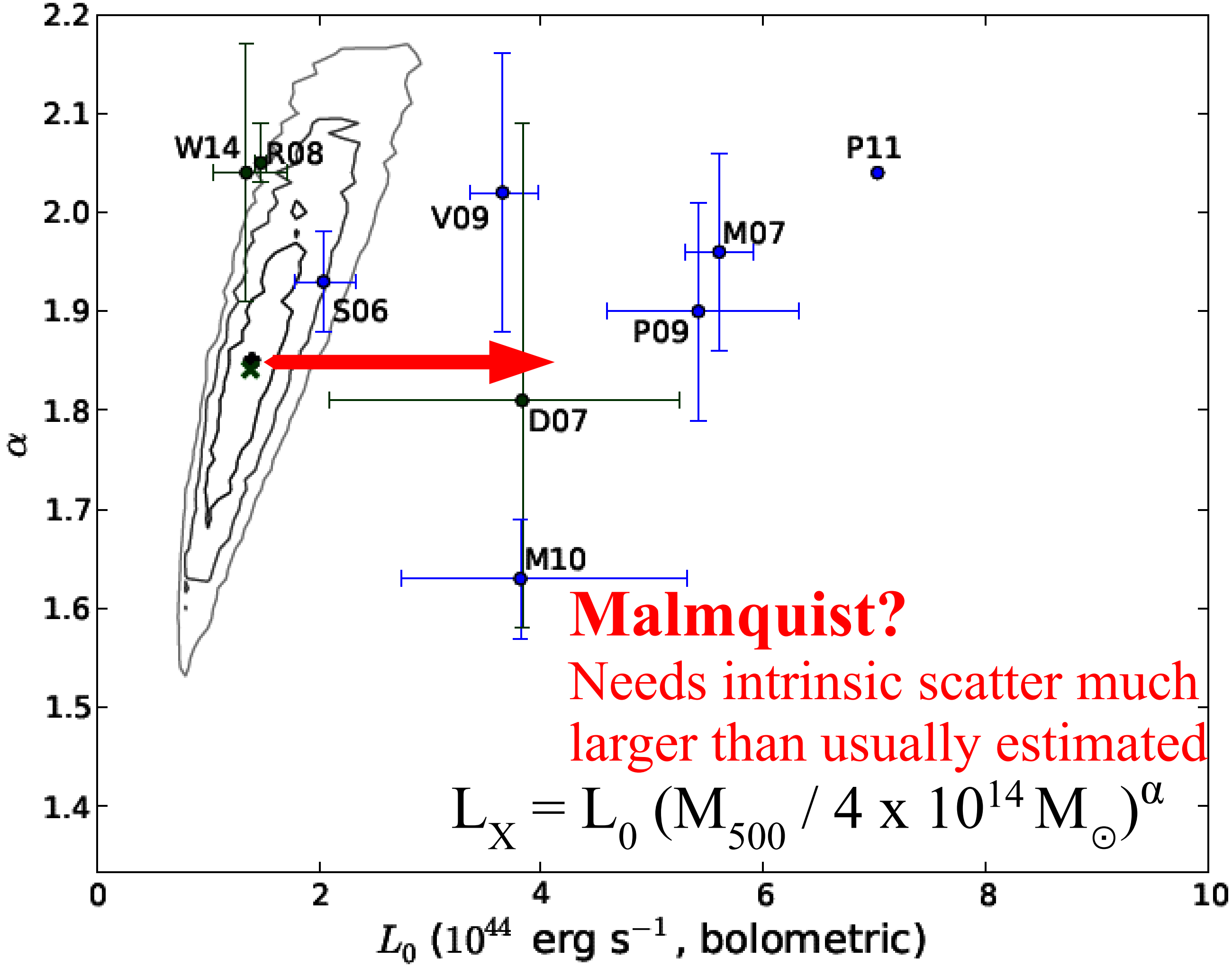
α = 4/3 is expected for self-similar halos with constant baryon fraction

X-ray luminosity grows much faster with mass than this

Forward modelling using the Guo13 mock LBG catalogue gives 1, 2 and 3σ ranges for the parameters of the $L_X - M_{500}$ relation

→ rough agreement with results for optically selected clusters
disagreement in normalisation with results for X-ray selected clusters

Stacked Rosat X-ray signal from LBGs



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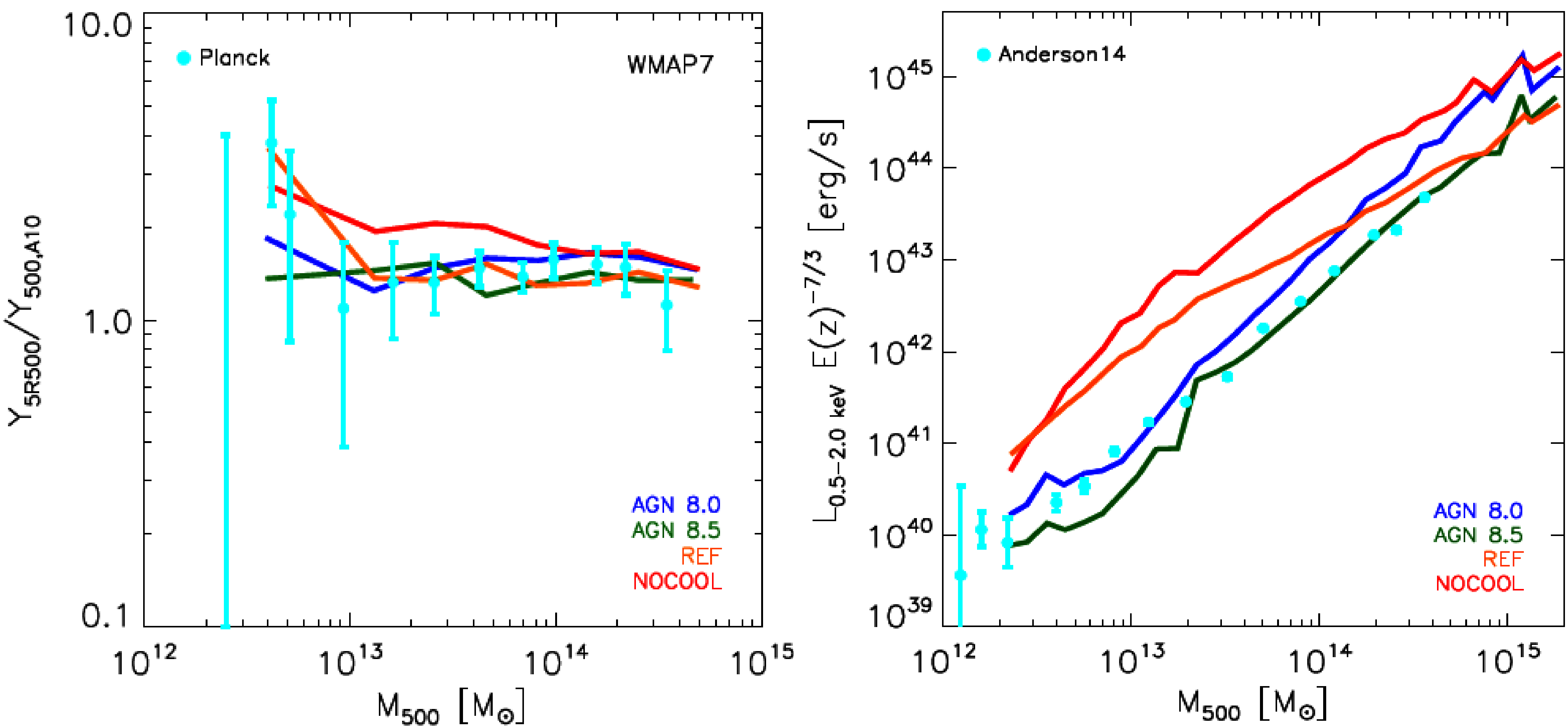
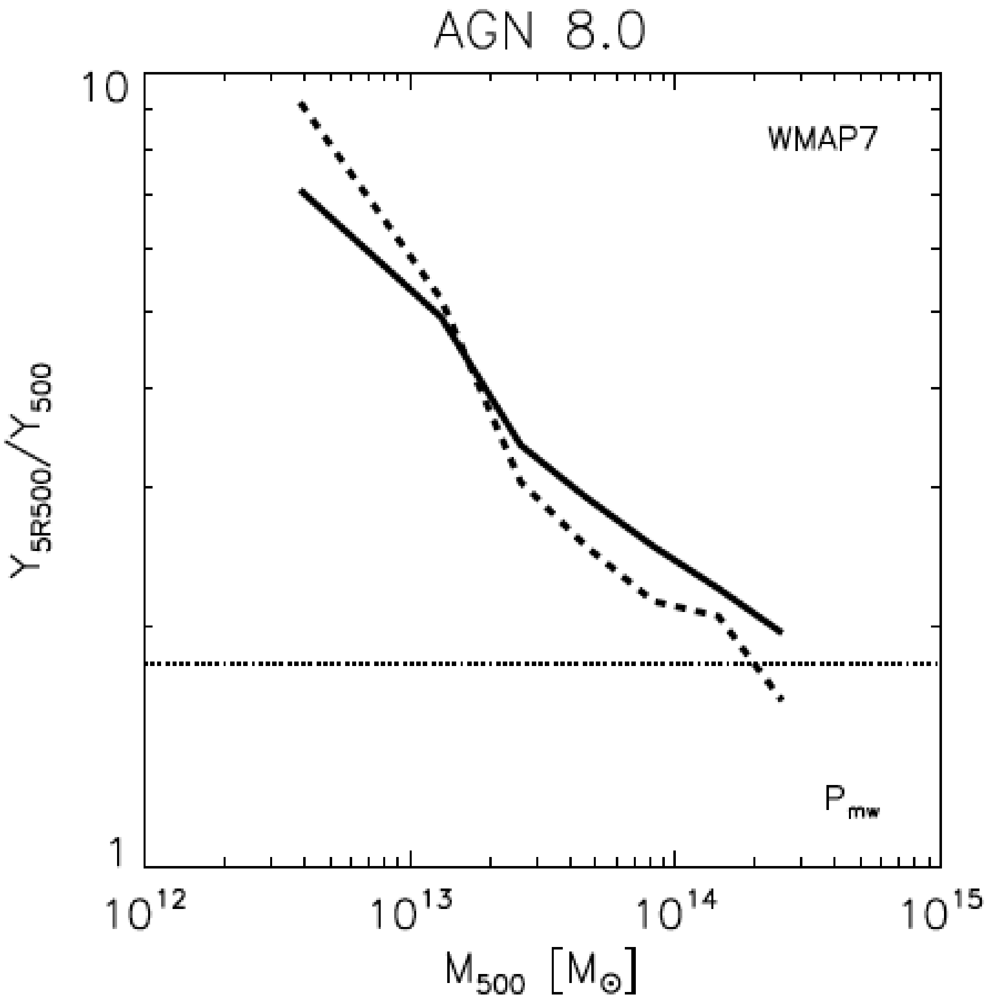
Le Brun, McCarthy & Melin 2015



With AGN feedback, the cosmo-OWLS simulations come close to reproducing *both* the nearly self-similar behaviour of the Planck SZ measurements and the non-self-similar behaviour of the ROSAT stacks

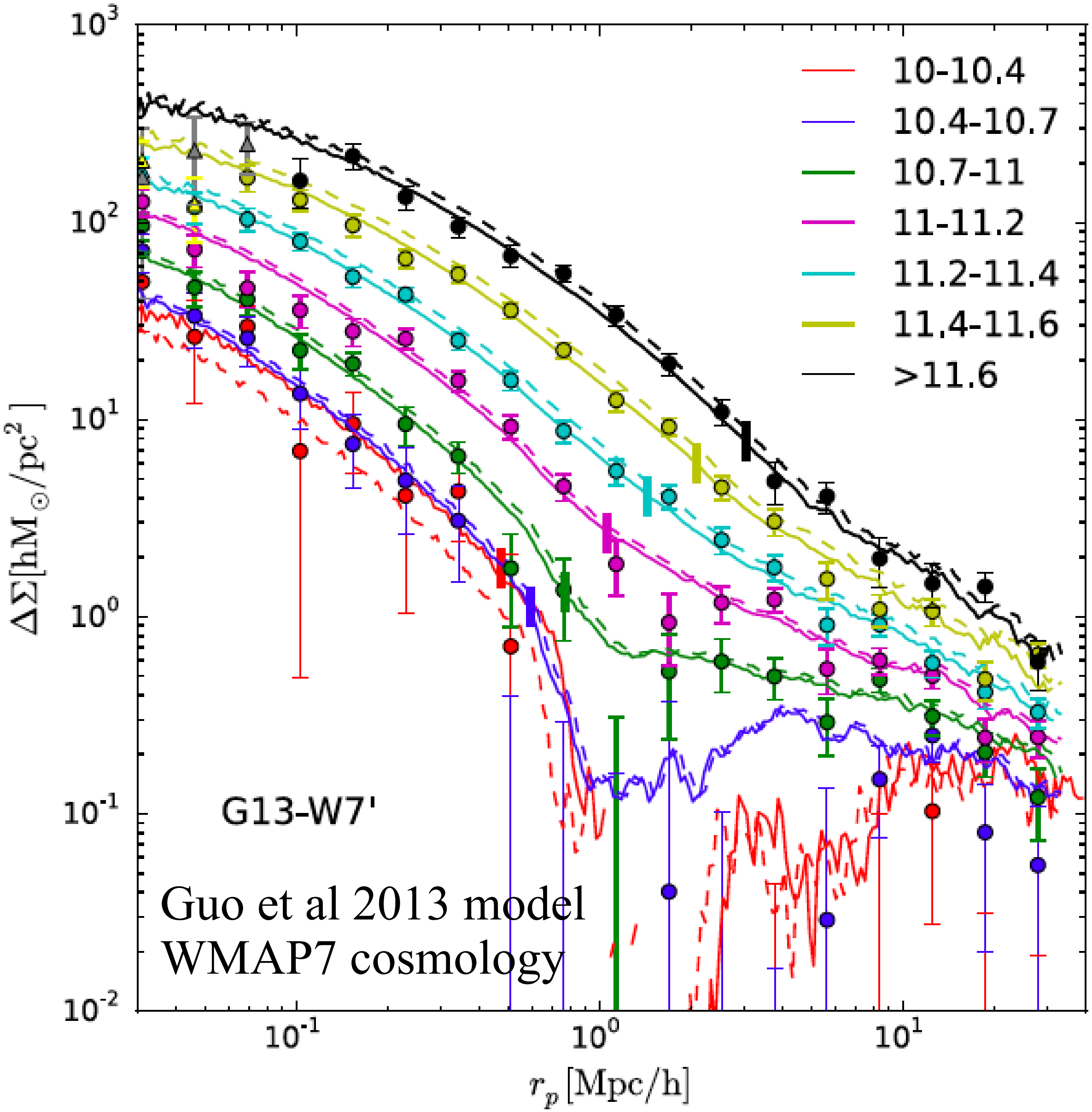
Le Brun, McCarthy & Melin 2015



With AGN feedback, the cosmo-OWLS simulations come close to reproducing *both* the nearly self-similar behaviour of the Planck SZ measurements and the non-self-similar behaviour of the ROSAT stacks

They predict the Y signal to be much less concentrated in low-mass halos

Stacked weak lensing signal from LBGs



Wang et al (2016)

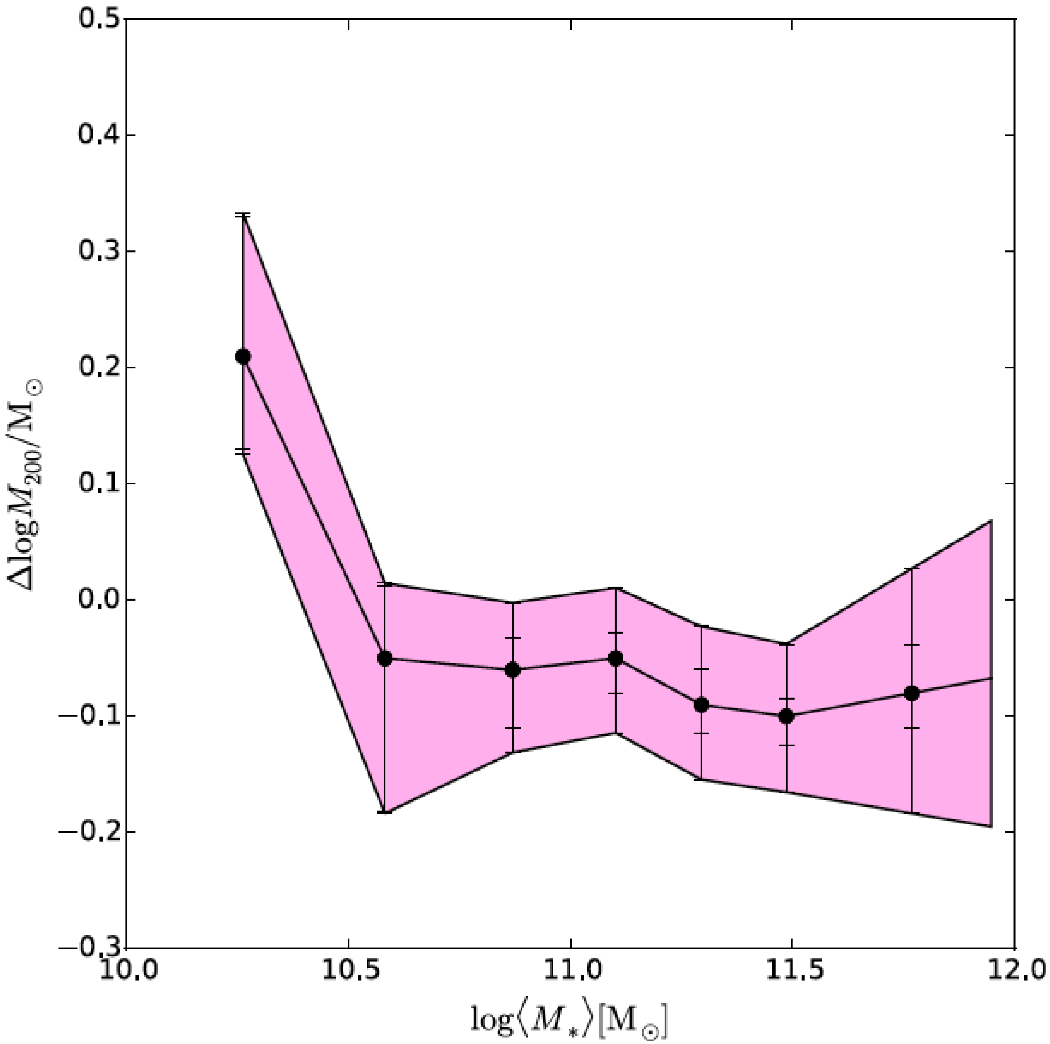
Points are results for SDSS/DR7

Dashed lines are results for locally brightest galaxies simulated in a WMAP7 cosmology (the simulation used before to calibrate the effective halos masses for the *Planck* and ROSAT stacking results)

Solid lines are these results scaled in mass to fit the 1-halo part of the lensing results as well as possible

Uncertainties in effective halo mass

Wang et al (2016)



There are two types of uncertainty in the lensing calibration of $M_{halo}(M_*)$

– observational uncertainties from the lensing measurements

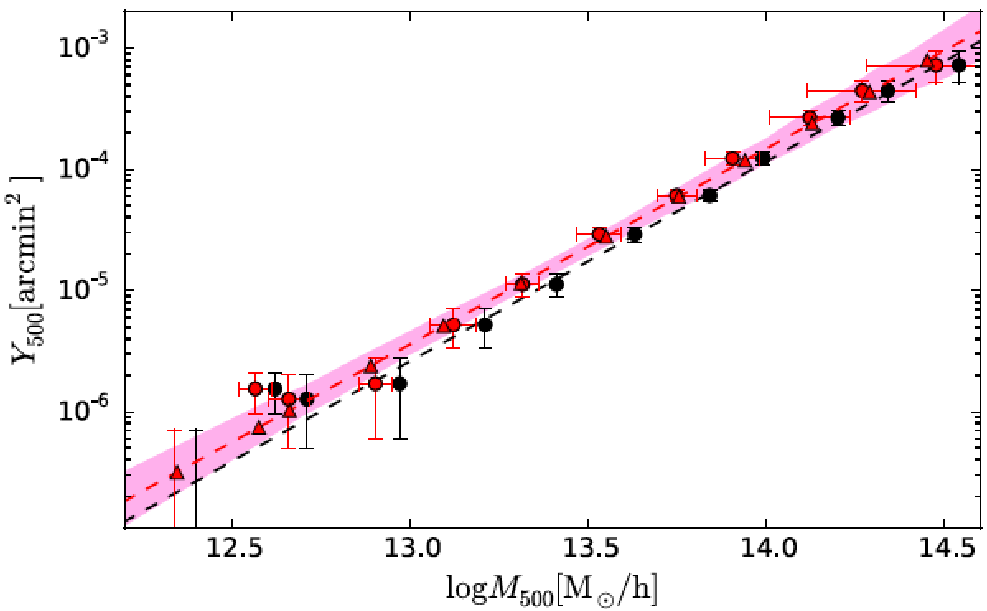
– model uncertainties from variations in the *shape* of the distribution of halo mass at given M_*

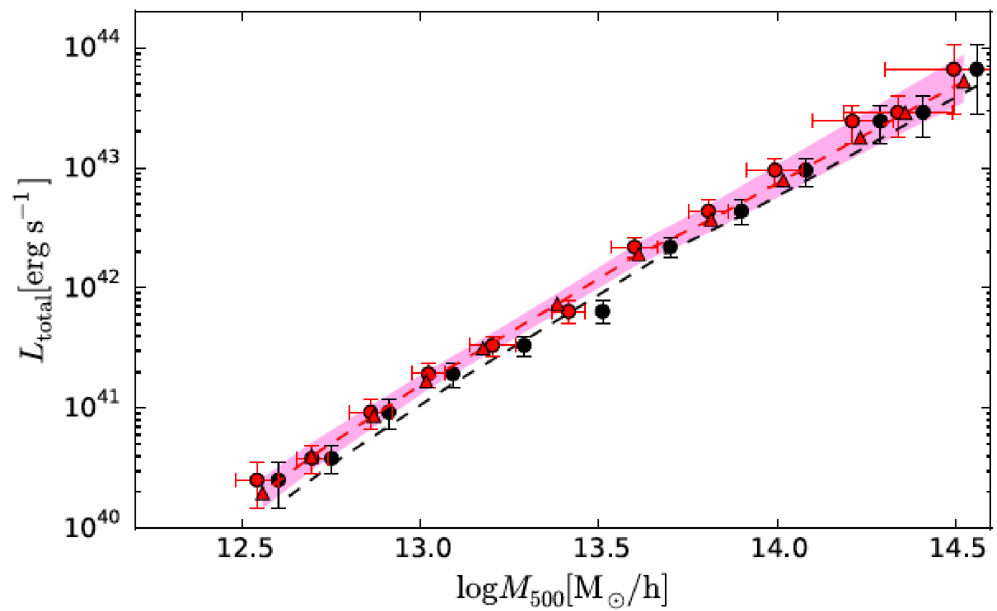
The first is dominant at small M_*

The second at large M_*

A lensing recalibration of halo scaling relations

Wang et al (2016)

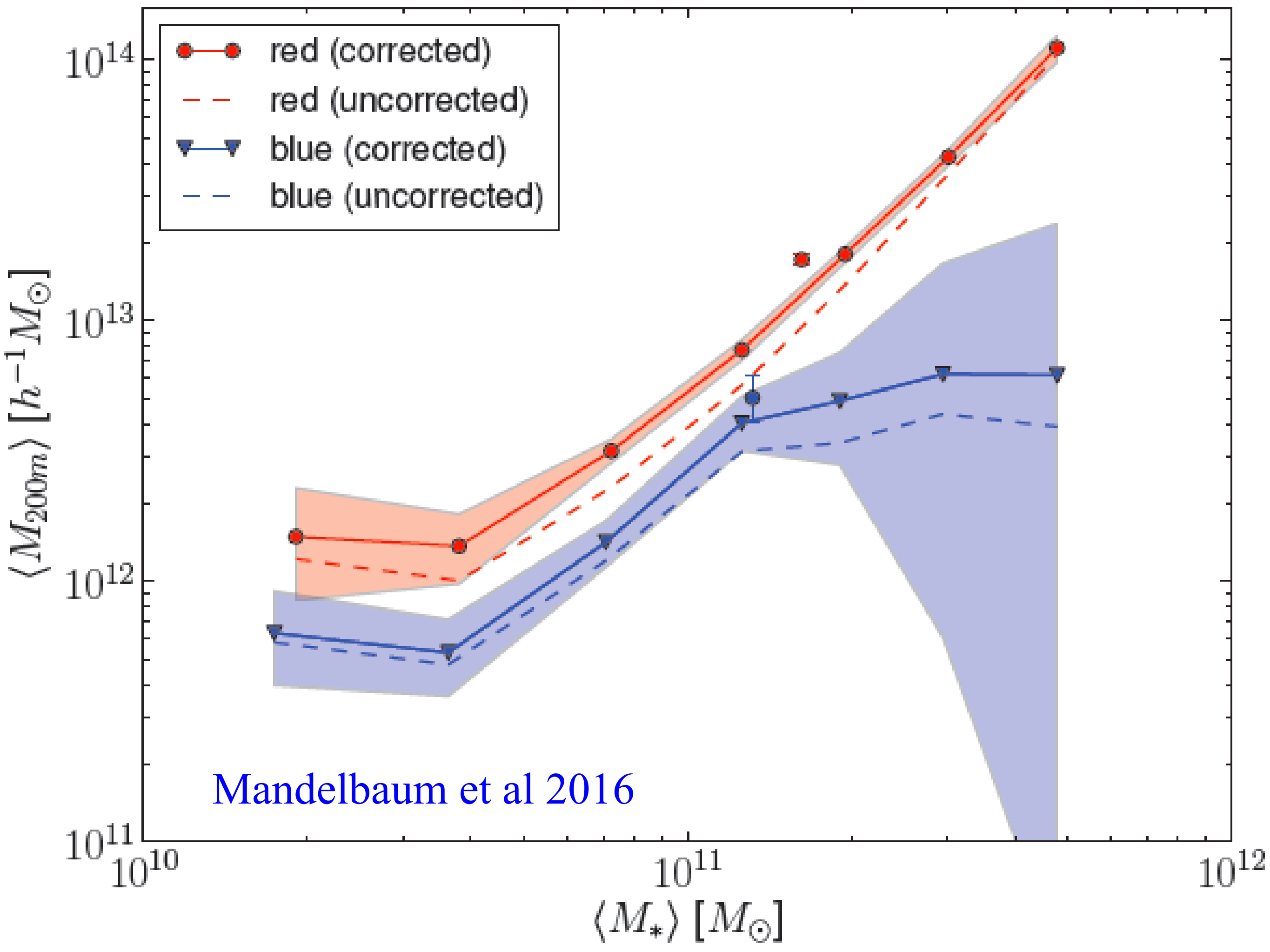




– The shifts from the earlier simulation-based calibration are small

– The uncertainty at high mass is too large to address the apparent conflict between *Planck* cosmological parameters from CMB and from cluster counts

Elliptical galaxies form <u>less</u> efficiently than spirals



Elliptical (red) galaxies are surrounded by dark halos which are twice as massive as those of spiral (blue) galaxies of the same stellar mass

Conclusions from Locally Brightest Galaxies in SDSS/DR7

- Planck detects SZ signal for LBG stacks with log $M_* > 11.0$
  ROSAT detects X-ray halos for stacks with log $M_* > 10.8$
  Both signals vary approximately as powers of M_* with no break

- Calibrating to halo mass with a simulation which matches the SDSS stellar mass function in a WMAP7 cosmology
  → $Y - M_{halo}$ as expected for self-similarity at the cosmic baryon fraction
  $L_X - M_{halo}$ substantially steeper than the self-similar prediction

- These can be reconciled if halo baryons are more extended in lower mass halos but still hot. This is consistent with AGN feedback simulations.
  → Planck has found the "missing" baryons from lower mass halos

- The calibration is confirmed and becomes (nearly) model-independent through lensing mass measurements of LBG halo mass

- Ellipticals have more massive halos than spirals of the same stellar mass